A BASIC APPROACH TO EVALUATING AND PREDICTING VP CREW PERFORMANCE

Edward Francis King

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A BASIC APPROACH TO EVALUATING AND PREDICTING
VP CREW PERFORMANCE

by

Edward Francis King

Thesis Advisor: W. M. Woods

March 1973

A BASIC APPROACH TO EVALUATING AND PREDICTING VP CREW PERFORMANCE

by

Edward Francis King
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1964

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 1973

ABSTRACT

A basic approach to the problem of evaluating or predicting a crew's performance for the VP community is presented. The method uses an application of multiple regression analysis techniques to a model which has training parameters as its variables.

The results would allow the squadron or wing commanding officer to predict a crew's performance before the actual flight and to determine how to allocate training time for the squadron.

TABLE OF CONTENTS

I. INTRODUCTION

A. BACKGROUND

The patrol squadron ASW (VP) community has been trying to determine a method of evaluating crew performance effectively for many years. They not only would like to evaluate a performance by a crew but also to predict a level of performance by a crew before the flight. The advantages of having such a system are obvious. A continuing performance chart of each crew, in each squadron would be available. With such a device WINGSPAC might be able to do away with yearly Operational Readiness Inspections (ORI). These evaluations have been used to check the ability of the squadron to meet any possible contingency. It was given through a multitude of flight, written examinations, and ground evolutions. Basically it tested the squadrons training program and determined if a squadron was ready for deployment. By having these up to date performance charts of all crews the Wing could tell at any time, not just at a scheduled one (as with the ORI), if that squadron was up to par.

On this same line the Wing commander could see from these charts if a certain squadron's overall performance trend was decreasing. If this was accompanied by a heavy period of operational tasking it could mean the squadron should be stood down from operational flying so it could devote more time to training. The problem of over tasking a squadron with operational commitments is a serious problem today facing the Wing commander.

In addition the squadron or Wing commander would be able to determine before the flight if a particular crew is qualified to go on that mission and do a job of a required degree of skill and competence.

B. NATURE OF THE PROBLEM

At the present time squadrons in WINGSPAC are using a postflight evaluation method in an attempt to evaluate a crew's performance. The crew is evaluated by a team of debriefers from the various ASCAC'S upon completion of the flight. The form is quite lengthy and requires considerable time to complete during the debrief and after. The range of grades goes from 0 to 100 for each area. The number of required areas to be graded being dependent on the type of flight flown.

The major problem here is the standardization of the evaluators in how they grade. The variance in their attempts for objectivity in quantifying quality has been extremely high. Another area for concern is the length of the form. This combined with the large number of flights graded and relatively small number of evaluators available causes a rushed evaluation with not enough emphasis on constructive criticism. Last but not least is the fact that the evaluators are not completely devoid of personal connections to the people they are evaluating.

Because of the above problems the average grade of a sample of flights of crews from several squadrons at Moffett Field is the unbelievably high 96-97% and is attacked by WINGSPAC and the Tactical Support Center (TSC) at Moffett Field now.

The problem that is attacked here is that of predicting a crew's performance. This problem is difficult because of the large number of variables affecting performance and the lac of, in some cases, of a suitable measure of that variable.

Because of this it was decided to start by looking strictly at the major variables associated with training. The amount and type of training might vary between squadrons but it is recognized as being a major necessity for all VP crews.

A basic approach using multiple regression analysis was then undertaken with the selected training variable as independent parameters and the postflight evaluation score as the dependent variable.

The inability of the squadrons to collect data in the required format did not allow us to use real world data to test proposed models. Data was generated by the author, however, to demonstrate the techniques involved. The data used is a reasonable attempt to simulate the actual data, based on prior experience.

II. METHODOLOGY

A. THE MODEL

The independent variables chosen to be looked at are:

X_2 : Total flight time - the time in hours flown as a crew since the crew was formed,

X_3 : Weapons Systems Trainer (WST) time - time in hours in trainer as a crew.

X_4 : Sub time - time in hours of actual on station time working a submarine as a crew.

The dependent variable is:

X_1 : Postflight evaluation score - overall grade of evaluators given as a percent.

It is expected that the value of X_1 would increase with an increase in the independent variable. The rate of increase should decrease as the independent variables get larger. One method of mathematically describing such a relationship is given by:

$$X_1 = 1 - \beta e^{-(\alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4)} \tag{1}$$

where

$0 \leq X_1 \leq 1$

$0 \leq \beta \leq 1$

$X_2, X_3, X_4 \geq 0$

Let $Z = \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4$. In equation (1) as the value of Z approaches infinity then the value of X_1 approaches 1 because the value of $e^{-\infty} = 0$. Similarly as the value of Z approaches 0 then the value of X_1 approaches β because $e^{-0} = 1$.

This relationship is shown graphically in Figure (1):

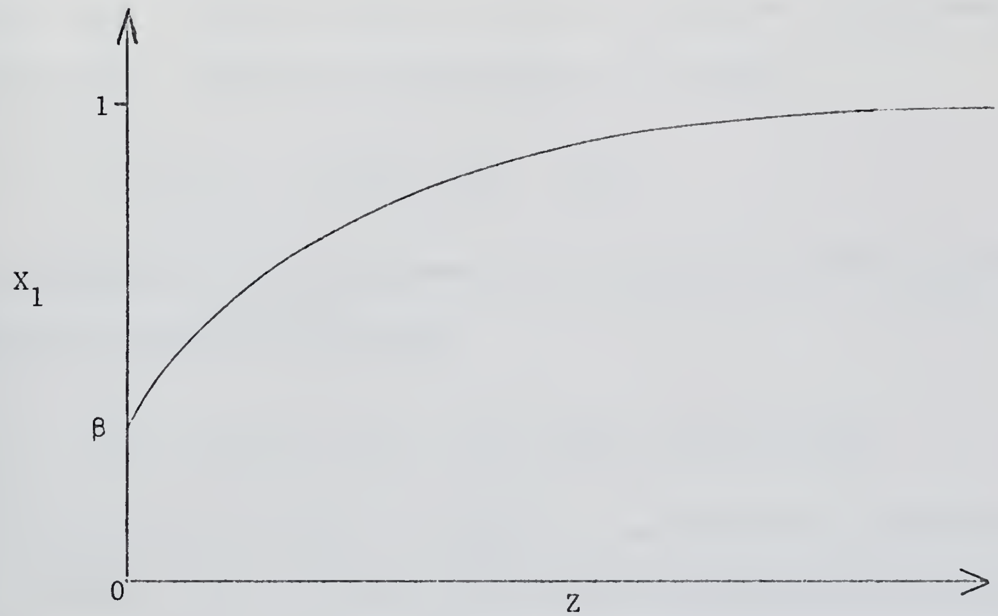

Figure (1)

B. APPLICATION

Before the model could be used in a linear regression analysis it had to be transformed from its non-linear form in equation (1) into a linear form. This can be done by using a logarithmic transformation on equation (1). Regrouping terms equation (1) becomes

$$1 - X_1 = e^{-(\alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4)} \qquad (2)$$

Now applying the transformation by taking the natural logarithm of both sides equation (2) becomes

$$y = \ln (1 - X_1) = \ln\beta - \alpha_2 X_2 - \alpha_3 X_3 - \alpha_4 X_4 \qquad (3)$$

The natural base for the logarithm was chosen for convenience only.

In this form it is ready to be used in conjuntion with any available computer multiple regression package. The author has used the BIMEDO2R stepwise linear regression package [Ref. 1] on the IBM 360 computer. This program allows variables to enter one at a time and permits the user to see in what order and with what effect each does.

For manual calculations let $\hat{b}$ be a vector containing the estimators of the constant term $\ln\beta$, α_2, α_3, and α_4. Let $\gamma = \ln\beta$.

$$\hat{b} = \begin{bmatrix} \hat{\gamma} \\ \hat{\alpha}_2 \\ \hat{\alpha}_3 \\ \hat{\alpha}_4 \end{bmatrix}$$

where the symbol $\hat{}$ indicates that a quantity is an estimator.

Let χ be a matrix of the observations on all independent variables augmented by a column of units representing the constant term.

$$\chi = \begin{bmatrix} 1 & X_{12} & X_{13} & X_{14} \\ 1 & X_{22} & X_{23} & X_{24} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ 1 & X_{n2} & X_{n3} & X_{n4} \end{bmatrix}$$

and χ' is χ transpose

$$\chi' = \begin{bmatrix} 1 & 1 & 1 & \cdots & 1 \\ X_{12} & X_{22} & X_{32} & \cdots & X_{n2} \\ X_{13} & X_{23} & X_{33} & \cdots & X_{n3} \\ X_{14} & X_{24} & X_{34} & \cdots & X_{n4} \end{bmatrix}$$

Let y be a vector of observations of the dependent variable.

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ \cdot \\ y_n \end{bmatrix}$$

The least squares estimates are given in matrix notation by

$$\hat{b} = (\chi'\chi)^{-1} \chi'Y \qquad (4)$$

If the problem was reduced to only one independent variable, equation (3) would simply be

$$\ln (1 - X_1) = \ln\beta - \alpha_2 X_2$$

or by some basic substitutions

$$y = A + BX$$

where $A = \ln\beta$ and $B = -\alpha_2$

Solving for the estimates of A and B by linear regression the results are:

$$\hat{A} = \bar{y} - \hat{B}\bar{X}$$

$$\hat{B} = \frac{\sum_{i=1}^{n} (X_i - \bar{X})(y_i - \bar{y})}{\sum_{i=1}^{n} (X_i - \bar{X})^2}$$

where the $\bar{\ }$ denotes the mean value of all observations of that variable.

A point estimate of y given a particular value of X can be found from the equation

$$\tilde{y} = \hat{A} + \hat{B}X^*$$

where $\tilde{y}$ is the point estimate and X^* is a particular value of X.

To use the t-test we must solve for the standard deviation of $\hat{B}$. This is given by

$$\sigma_{\hat{B}} = \sqrt{\frac{\sum_{i=1}^{n} (y_i - \bar{y})^2}{n - 2 \sum (X_i - \bar{X})^2}}$$

The confidence interval for B is

$$\hat{B} \pm t_{c/2, n-1}\, \sigma_{\hat{B}}$$

C. DATA COLLECTION

Data has to be collected by the fleet to test the model. It could be done in the following manner. For any flight that is to be graded the tactical coordinator of the crew can give the values of the variables X_2, X_3, X_4 either during the brief or the debrief. After the evaluators have finished grading the flight they will record the overall score as variable X_1 and turn into collection point along with squadron, crew, event number, and date. These values of X_1, X_2, X_3, and X_4 form one set of observations. When a reasonable number have been gathered they can be used with the regression package and run on the computer or using formulas (4) and a calculator the model can be tested and the estimators found. Once the estimator of the constant $\ln\beta$ and the estimators of the coefficients α_2, α_3, and α_4 have been determined these values can be used to predict future values of the dependent variable X_1.

III. DATA ANALYSIS

Summary of computer results using data in Table 1

	coefficient	standard error
X_2	-.00105	.00076
X_3	-.00698	.00272
X_4	.00172	.00994
constant	-.97327	
multiple R	.8859	
R square	.7848	

A t-test is used to test the hypothesis that the value of $\hat{\alpha}_i$ is equal to ϕ. The hypothesis is accepted if

$$- t_{c/2,n-1} \leq \frac{\hat{\alpha}_i}{\sigma_{\hat{\alpha}_i}} \leq t_{c/2,n-1} \qquad i = 2,3,4$$

and rejected if $\frac{\hat{\alpha}_i}{\sigma_{\hat{\alpha}_i}}$ lies outside this interval. In the avove equation c is equal to 1- confidence level desired and n-1 is called the degrees of freedom, where is the number of observations.

A t-table can be found in [Refs. 2,3,4, and 5] and many other textbooks. Part of a typical table is shown below:

df. = n-1 \ c/2	.1	.05	.025
30	1.310	1.697	2.042
40	1.303	1.684	2.021
50	1.298	1.676	2.009

One would enter with the degrees of freedom (df) equal to n-1 down the left column and the value of c/2 across the top.

For a 90% confidence level for the given data we would enter with df = 39 and c/2 = .05. The value obtained was 1.685

$$- 1.684 \leq - \frac{.00105}{.00076} \leq 1.684$$

$$- 1.684 \leq - 1.381 \leq 1.684$$

This tells the user that the coefficient is not significant at the 90% confidence level or that it is equal to ϕ at this level. It can be seen from the t-tables that it becomes significant at the 80% level. The t value being 1.303.

Similarly $\hat{\alpha}_3$ can be tested. Using a 90% confidence level

$$- 1.684 \leq - \frac{.00698}{.00272} \leq 1.684$$

$$-1.684 \leq - 2.564 \leq 1.684$$

Here $\hat{\alpha}_3$ is significant and different from 0.

Just by looking at the computer results for $\hat{\alpha}_4$ it can be seen that the standard error is considerably larger than the coefficient itself. This indicates that $\hat{\alpha}_4$ is not significant at any practical level of confidence.

Another important figure in the results is the R square. This indicates that 78% of the variance in the data is accounted for by the model and its significant variables.

Since a logarithmic transformation was used on the model any term in the final results so affected has to be transformed back to its usable form in the model. Here only the constant term is affected. Taking the antilog of -0.97327 with a natural base the resulting value is .3779.

The equation for predicting future scores would be

$$X_1 = 1 - .3779e^{-(.00105X_2 + .00698X_3)}$$

With the data used the values of $\hat{\alpha}_2$ and $\hat{\alpha}_3$ indicate the relative weighing factors of the training parameters X_2 and X_3. Since $\hat{\alpha}_2 = .00105$ and $\hat{\alpha}_3 = .00698$, it would indicate that the training denoted by X_3 would have approximately 6.5 times the effect on performance as the training denoted by X_2. Again this is strictly for the data used in this analysis.

IV. CONCLUSIONS

The approach to the problem is only a basic feasible starting point. The model presented may be one of many possible ones. The fleet has to take the model presented and test it with actual data collected on a higher authority basis, using the methodology presented here. The numerical results found here do not apply to the fleet because they were arrived at using generated data. The implications from the tests show that the model could work and should be tested. Once this is done the estimators that are found can be used to predict the performance of any crew on a pending flight.

An important secondary use of these coefficient estimators is as a weighting factor to determine allocation of training time within a squadron. The coefficients form a relative merit scale of each parameter used in the regression.

The user can add as many independent variables as he chooses without complicating the methodology. Since the BIMED02R is a stepwise regression model, the user is able to determine the effect of these variables individually if he can collect the data in a usable form.

APPENDIX A

DATA USED FOR SAMPLE ANALYSIS

OBS NO.	X_2	X_3	X_4
1	231	20	12
2	20	8	0
3	30	8	4
4	38	11	4
5	54	11	4
6	64	14	4
7	830	152	64
8	842	152	64
9	850	152	64
10	878	155	68
11	902	158	68
12	453	45	38
13	461	48	38
14	490	51	2
15	498	54	42
16	513	57	42
17	240	23	16
18	252	26	16
19	261	26	20
20	270	29	20
21	136	20	4
22	492	86	48
23	316	72	44

OBS NO.	X_2	X_3	X_4
24	224	44	24
25	84	20	1
26	524	120	40
27	185	45	8
28	381	57	24
29	204	12	4
30	523	60	36
31	620	120	40
32	450	72	32
33	362	28	20
34	180	24	12
35	532	100	40
36	1226	147	83
37	239	21	16
38	781	68	54
39	796	106	58
40	93	18	7

BIBLIOGRAPHY

[1] BMD Biomedical Computer Programs, University of California Publications In Automatic Computation, V. 2, University of California Press, 1971.

[2] Bowker, A. H. and Lieberman, G. J., Engineering Statistics, Prentice-Hall, 1959.

[3] Hoel, P. G., Port, S. C., and Stone, C. J., Introduction to Statistical Theory, Houghton Mifflin, 1971.

[4] Johnson, J., Econometric Methods, McGraw-Hill, 1972.

[5] Theil, H., Principles of Econometrics, Wiley, 1971.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Professor W. M. Woods, Chairman Code 53Wo Department of Mathematics Naval Postgraduate School Monterey, California 93940	1
4.	Professor R. N. Forrest Code 55Fo Naval Postgraduate School Monterey, California 93940	1
5.	LCDR Edward F. King (USN) USS Coral Sea (CVA - 43) FPO San Francisco	1
6.	Commander Fleet Airwings, Pacific U.S. Naval Air Station Moffett Field, California 94035 ATTN: CDR Kneisl	1
7.	Chief of Naval Personnel Pers. 11b Department of the Navy Washington, D.C. 20370	1
8.	Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

ORIGINATING ACTIVITY (Corporate author) Naval Postgraduate School Monterey, California 93940	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

REPORT TITLE

A BASIC APPROACH TO EVALUATING AND PREDICTING VP CREW PERFORMANCE

DESCRIPTIVE NOTES (Type of report and, inclusive dates)

Master's Thesis; March 1973

AUTHOR(S) (First name, middle initial, last name)

EDWARD F. KING

REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
March 1973	22	5

8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Naval Postgraduate School Monterey, California 93940

13. ABSTRACT

A basic approach to the problem of evaluating or predicting a crew' performance for the VP community is presented. The method uses an appli ation of multiple regression analysis techniques to a model which has training parameters as its variables.

The results would allow the squadron or wing commanding officer to predict a crew's performance before the actual flight and to determine how to allocate training time for the squadron.

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
CREW PERFORMANCE						
PREDICTION OF ASW CREW PERFORMANCE						
MULTIPLE REGRESSION ANALYSIS						
VP TRAINING ALLOCATION						

144045

Thesis
K427 King
c.1
A basic approach to evaluating and predicting VP crew performance.